

**Additions to the Knowledge of the Biology of
Conophthorus lambertianae Hopkins**

(Coleoptera : Scolytidae)

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The sugar-pine cone beetle, *Conophthorus lambertianae* Hopkins, attacks sugar pine (*Pinus lambertiana* Dougl.) cones in California and Oregon. Often it will kill all cones of some trees, and thus no seed is produced. Miller (1915) and Ruckes (1963) have summarized information on the biology of the sugar-pine cone beetle. Their reports taken together provide a reasonably complete description of the habits of *C. lambertianae*, including appearance of its stages, attack behavior, and seasonal development of both the insect and its damage. But the two accounts differ in several important areas and are incomplete in others. This study was started to clarify the biology of *C. lambertianae*.

Much of the life cycle of the sugar-pine cone beetle takes place 100 to 200 feet above the ground. This characteristic makes direct observation difficult and forces the observer to use more accessible indirect evidence of beetle activity, such as fallen beetle-killed cones. Both Miller and Ruckes collected freshly attacked cones from logging operations, but also relied on indirect evidence.

My observations will be limited largely to: (1) those that clarify differences between the two previous reports; (2) those that are in partial disagreement with either of the previous reports; and (3) those covering points not previously reported on, such as internal changes of beetles.

MATERIALS AND METHODS

The seasonal biology of the sugar-pine cone beetle was studied from populations near Strawberry, Tuolumne County, Calif., at 4200 and 6200 feet elevation in 1962. Binoculars were used to observe fading cones and twig tips on standing trees.

Fallen beetle-killed cones were collected weekly under the study trees. They were measured, examined for parent adult emergence holes, and randomly distributed to either a sunny or shaded site. Each week 18 cones were dissected from each site, before the current week's cones were added, to ascertain the developmental stages present. As brood adults began to appear, ten were dissected weekly to observe the condition of flight muscles and gonads. To augment field observations of

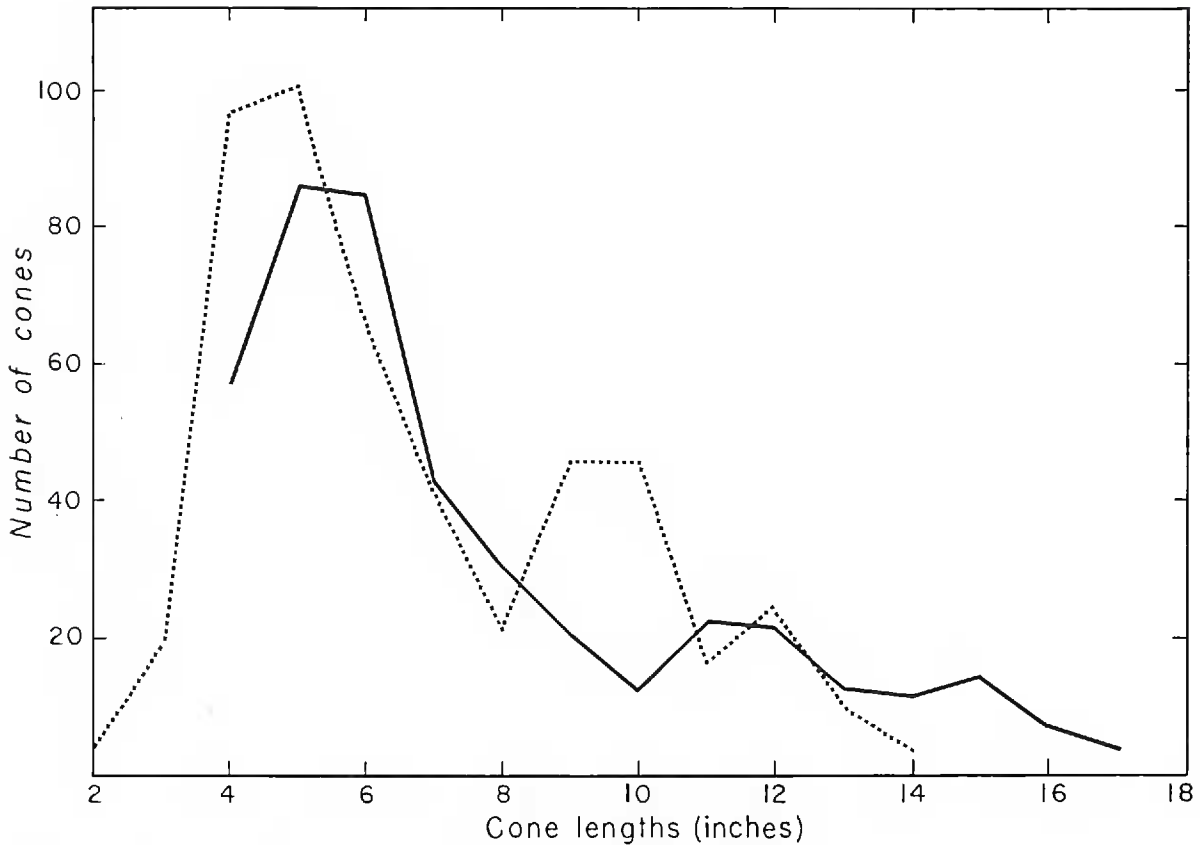


Fig. 1. Lengths of beetle-killed cones from two different trees, 1962.

emergence dates, insects were reared from infested twig tips taken from fallen limbs and limbs near the ground and from cones.

In 1964, periodic observations of cone and twig tip fades and fallen cones were made near Fish Camp, Mariposa County, Calif., at three elevations—3500, 4800, and 6000 feet. Freshly attacked cones from logging operations were put in rearing or dissected. Live parent adults from such cones were dissected or allowed to attack fresh green cones. In 1965 and 1966, in the higher study area near Fish Camp, the tip mining and cone killing were observed periodically. An examination was made of the internal organs of beetles found in twig tips and cones.

RESULTS

Both males and females were found overwintering in fallen cones and in twig tips on the tree and on the ground. Some tips still had needles attached; others did not. No sperm was found in the spermathecae of overwintering females. Beetles were not found in the duff layer taken from under two piles of more than 300 cones each. This search was made in late fall after many of the beetles had emerged from the cones which were piled in summer.

Females were observed starting their attack in a head-down position on the nearly vertical peduncle of pendant second-year cones; their

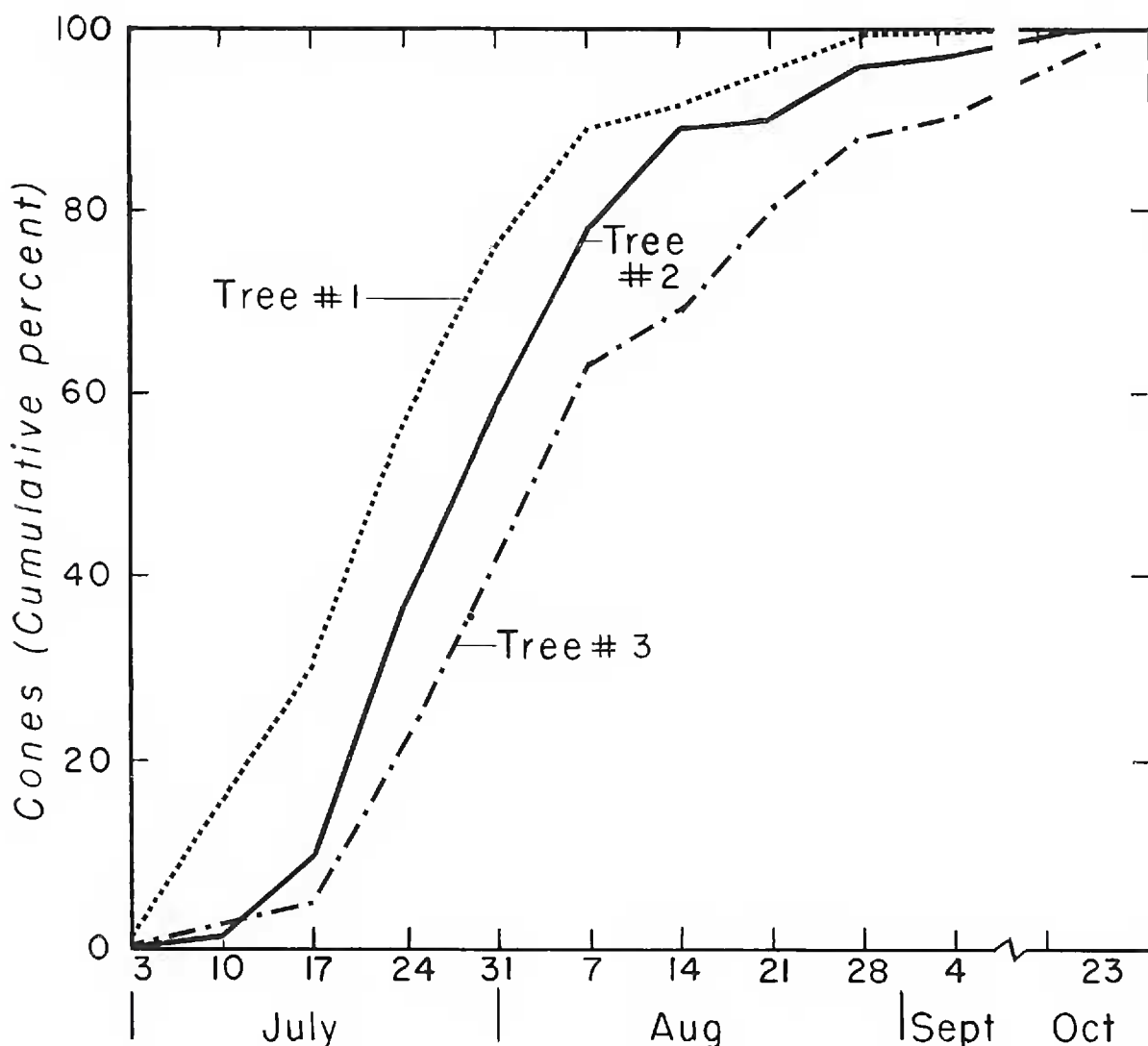


Fig. 2. Cumulative percent of beetle-killed cones fallen by given dates for three different trees. Basis: tree No. 1, 455 cones; tree No. 2, 515 cones; tree No. 3, 630 cones.

longitudinal body axis was parallel to the long axis of the peduncle. Once inside the peduncle, the female severed the xylem tissue by making a circumferential gallery. Next, she excavated a longitudinal gallery along the central axis of the cone through the bases of the cone scales. After the initial circumferential gallery was formed, one or more males or females or both entered the cone. One to nine adults were found in freshly attacked cones. When as many as nine were present not all had undergone the internal changes characteristic of the reproductive phase. No more than three females were found ovipositing in a single cone. Ovipositing females constructed individual or nearly individual egg galleries.

Parent adult emergence from freshly attacked cones reared outside was completed within 10 days. All of the emerged beetles that were dissected were in flight condition. Females not dissected were observed

TABLE 1. Beetle-killed cones containing parent adult emergence holes, by size classes, 1962.

Cone size classes (inches)	Number of cones	Percent of cones with parent adult emergence holes
3	20	66
4	154	46
5	197	44
6	151	47
7	86	38
8	52	35
9	67	21
10	59	22
11	40	27
12	48	19
13	24	7

to begin attacks, lay viable eggs, and reemerge in flight condition in 10 days, still with sperm in their spermathecae. Parent adults emerged when cones had lost enough moisture to become slightly flaccid, just before onset of hardening which characterizes advanced drying. No live parent adults were found in hardened cones.

The internal changes associated with the activity change from flight to reproduction and back to flight were similar to those described for other scolytids (Atkins and Farris, 1962; Reid, 1962) and for other *Conophthorus* (Henson, 1961; Schaefer, 1964). Males did not undergo complete reduction of wing muscles, but females did.

The attacked cones fell to the ground a month or two after they were killed (fig. 1). Between-tree variation, particularly in cone size, is seen in the comparison of the two trees of fig. 1. This general picture was representative of all study trees. All sizes of second-year cones were killed; however, cones 4 to 6 inches long were the most common size killed.

Parent adults emerged more often from smaller cones than larger cones (Table 1).

In 1962 I found that the seasonal activity of the sugar-pine cone beetle started 1 week later at 5200 feet elevation and 3 weeks later at 6200 feet elevation than Miller had found. But by the end of August 1962, development in both study areas had reached about the same point and was in agreement with Miller's report. Half of the beetle-killed cones had not fallen until 1 August under 1962 study trees (fig.

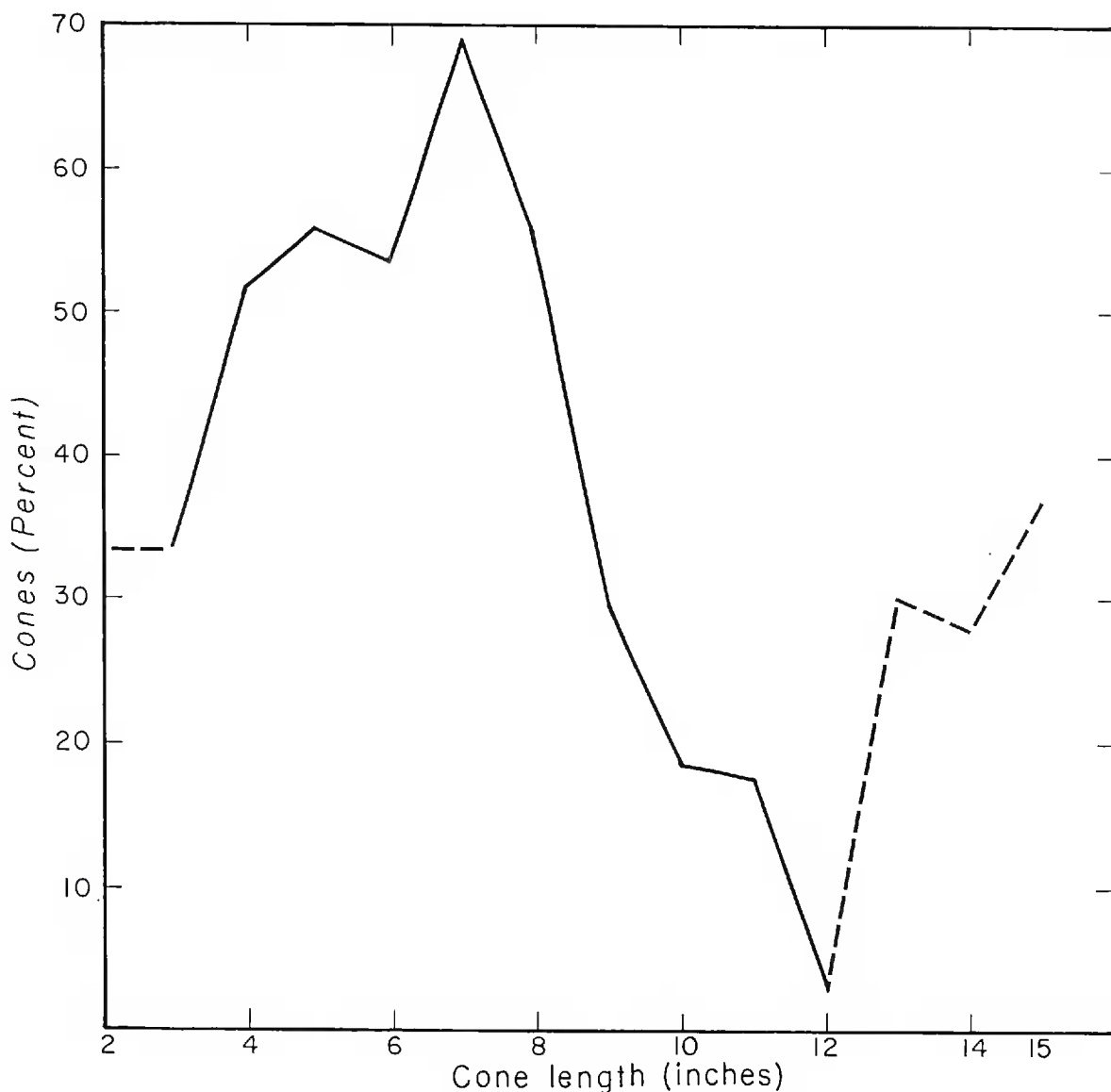


Fig. 3. Percent of cones with more than two brood emergence holes in various cone size classes. Basis: 393 cones. Intermittent line connects points of < 20 cones samples.

2), whereas Miller's table shows most of his study cones fell before mid-July.

Pupae transformed to adults from mid-July to mid-August. These callow adults appeared fully pigmented 10 days after transforming from pupae, but dissections and flight tests showed they could not fly for another 3 weeks.

Emergence activity of brood adults was evidenced by the appearance of perfectly round holes, some of which bore fine yellow frass, on the surface of cones. These holes extended into the cone as a perfect cylinder. (Parent adult emergence holes do not have this perfect form because they become distorted in the process of cone drying.) The success of broods, as indicated by brood emergence holes in cones, varied in cones of different sizes (fig. 3).

Starting in mid-August some brood adults left cones and flew to and mined individually in the current year's growth of small-diameter sugar pine twig tips. This pattern became more pronounced as fall approached. Many faded twig tips were seen in late October, but many beetles still remained in the cones.

Freshly mined twig tips have been found abandoned as early as September. In midwinter more tips were found abandoned. And by early April—presumably before cone attack—only about one-quarter of the mined twig tips with needles still attached were occupied.

Both male and female brood adults in both twig tips and cones had very reduced wing muscles, large fat bodies, mature sperm in one-third to one-half of the testes, and no sperm in the spermathecae. Two exceptions to this are: (1) the brief period before emergence when the shift to flight condition is occurring and (2) the 3 to 4 weeks of adult maturation following transformation from pupae.

In spring 1965, in the highest study area near Fish Camp, virtually no second-year cones were available for the large overwintering cone beetle population. By then faded twig tips which had contained overwintering beetles were found vacant, but freshly mined twig tips were found. These twigs faded during bud or needle elongation or both (fig. 4). They contained pitch tubes at the entrance hole and were usually occupied by live beetles. By fall many of these tips were abandoned, and many fresh tips were being mined. In early spring 1966, cone beetles were still alive in these fall-mined twig tips. All this activity occurred in areas where virtually no 1965 broods were produced in cones.

In 1962 studies, October observation revealed that fewer beetles emerged from cones which fell before 4 September and remained in a cool, shady place than emerged from cones which stayed on the trees longer and fell after 4 September. Both groups of cones had cones that were attacked about the same time. Presumably the two groups of cones experienced different environments. By 20 September 1964, virtually all beetles had left the 1964 brood cones at the lower elevation, but some brood was still present in the brood cones of the study area at higher elevation.

DISCUSSION

The sugar-pine cone beetle overwinters in two known places: fallen cones and mined twig tips (which may be either on the tree or fallen). The proportion of the population overwintering in these locations varies. Miller found that in the first 2 years of his study the entire population



Fig. 4. *Pinus lambertiana* twig tip mined by *Conophthorus lambertianae* in spring. Pitch tube at base of bud killed during the tip's elongation.

overwintered in cones, and that in the third year all insects overwintered elsewhere (presumably in twig tips, though he did not specify). Limited observations indicate that more beetles leave cones in the warmer locations than in cooler locations. The fact that beetles were not found in duff samples is certainly not a very positive indication that hibernation in the duff does not occur. But it seems fairly certain that beetles which leave fallen cones leave the immediate vicinity.

Miller had suggested controlling beetles by destroying cones with broods as late as November. The method would not be effective because, generally, enough beetles leave the cones during August and Sep-

tember. However, a high proportion of the local population could be destroyed in cones on the ground in early August for early-falling cones, and late August or early September for late-falling cones.

Individual beetles may mine more than one twig tip between September and late May. This conclusion is based on the number of recently abandoned twig tips found during the overwintering period.

It is surprising and significant that sugar-pine cone beetle females can change from flight condition to reproductive condition and back again to flight in only 10 days. A single female possibly could kill as many as five cones from late May to July. Figures for rate of internal changes of other species under similar temperatures are not available. However, under cooler conditions *Dendroctonus pseudotsugae* Hopkins females took 10 days and males took 25 days to complete reduction of flight muscles, and possibly 40 to 50 days to complete the cycle from flight condition to reproductive condition and back to flight condition (Atkins and Farris, 1962). If this duration and that of other scolytids are considered, then the sugar-pine cone beetle's shift from flight to reproduction and back to flight appears remarkably rapid indeed.

Reid (1962) reported that internal changes of female mountain pine beetle (*D. ponderosae* Hopkins (= *D. monticolae* Hopkins)) are influenced by host moisture content. He found drying of host tissues was associated with the change from reproductive condition to flight condition. An analogous relation may exist between the sugar-pine cone beetle and the moisture levels in its host tissues.

My data strongly support Miller's report that the sugar-pine cone beetle has one generation yearly. Some brood adults are present in cones during the last attacks on ripening cones. But, in the instances studied, these adults were not in condition to emerge and did not start to emerge until a month after final cone attack. These beetles attacked twigs or remained in brood cones.

Further, the long attack period of this cone beetle can be appropriately explained by the reemergence and reattack of parent adults. The rate of elongation of second-year cones is roughly constant during the period of beetle attack—late May to early July.¹ Therefore, the horizontal axis of fig. 1 and size classes of Table 1 are also a rough time scale.

The reconstructed seasonal activity, based on the evidence offered by these cones, is as follows: Early attacks were associated with a high proportion of reemerging adults. But as the season progressed, both

¹ Krugman, S. L. Unpublished data on file at Pacific SW. Forest and Range Exp. Sta., U. S. Forest Serv., Berkeley, Calif. 1959.

the proportion of reemerging adults and the number of subsequently attacked cones progressively decreased (Table 1). The parent adult emergence holes—especially in cones > 7 inches long—demonstrate that parent adult beetles were active when the last attacks of the season were being made. Further, damage did not increase late in the attack season. Such an increase would be expected if there were an increase in the attacking population brought about by brood adults.

The internal condition of beetles in cones and twig tips suggests the quiescency reported for *C. radiatae* Hopkins by Schaefer (1964). He found reduced respiration associated with similar internal conditions and with similar periods of feeding without reproducing.

This quiescency allows the beetles to survive when cones are not available for insect reproduction. The period for *C. lambertiana*e is usually late summer, fall, and winter. But if the beetles fail to find cones in which to reproduce, the period may extend through these three seasons plus an additional year. This latter conclusion is based on evidence provided by areas where 1964 brood adults appeared to survive the 1965 summer without cones and without reproducing, and became available in the spring of 1966.

Murdoch (1966) has reported that the carabid, *Agonum fuliginosum* (Panzer), has similar habits. The beetles normally overwinter as young adults which reproduce in the summer and rarely live a second winter. But when food limits the reproductive activity of the beetles, many do live through a second winter. Another example of adult longevity brought about by a food-induced delay in reproduction is reported for the coccinellid, *Hippodamia convergens* Guérin-Ménéville (Hagen, 1962).

Quiescency in *C. lambertiana*e is in agreement with similar mechanisms of delayed development common in other insect species which depend on variable cone crops. Many of these species have mechanisms of synchronizing their seasonal development with that of their host. And these same mechanisms may also provide a basis for synchronizing them with the year-to-year fluctuations in food supply. For example, Hedlin (1964) reports that populations of the cone pests *Contarinia oregonensis* Foote and *Barbara colfaxiana* (Kearfott) vary in the proportion which diapause more than 1 year. The variations are large enough that they must be taken into account in predicting the amount of insect damage to cone crops.

The yearly cone production in the host species of *C. radiatae* (Monterey pine, *Pinus radiata* D. Don) is much more regular than in the host species of *C. lambertiana*e (compare Roy's [1966] findings with

those of Fowells and Schubert [1956]). The biology of *C. radiatae* differs from the biology of *C. lambertiana*e in three respects which could be related to this regularity of the reproductive resource: Some *C. radiatae* mate in brood cones; they do not emerge in fall to mine twig tips; and, apparently, they therefore lack a means of surviving local year-to-year cone crop failures. However, they do possess, as does *C. lambertiana*e, the capacity for quiescency. This capacity enables them to survive the seasonal absence of the reproductive resource.

Until further information becomes available, the relative success of broods in cones of different sizes cannot be explained. But eggs are not laid in many of the smallest and largest cones. Premature mortality is often associated with failure to oviposit in larger cones, whereas many small cones are attacked, bored through, and emerged from apparently without oviposition. This latter pattern is similar to that reported for *C. coniperda* (Schwarz) (Godwin and Odell, 1965).

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New and Interesting North American Trichoptera

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The new species described herein represent very interesting additions to the known species of Trichoptera. The new *Atopsyche* presents several developments not yet described in other species. A new *Cyrptochia*, the fifth species in this interesting and virtually unknown genus, is described. A new genus is erected to accommodate a new member of the Goeridae—a highly specialized family of which very little is known.

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Atopsyche cordoba Denning, new species

This new species belongs to the *bolivari* group and of the described species is probably closest to *A. dampfi* Ross. Distinguishing characters are the dentate paracercus, the spinous processes of the aedeagal lobe, and the large pocket of scales on the hind wing. The presence of scales has not been reported from other species.

MALE.—Length 8-9 mm. Forewings brownish, densely covered with dark brown hairs especially heavy at pterastigma; hind wing with M bearing a few black scales at branching of M_{1+2} and M_3 , stem of Cu_1 bearing a row of black scales, Cu_2 about midway covered by a large elliptical-shaped pocket of densely packed black scales; intervenous membranous area of anal veins brownish and more heavily sclerotized than remainder of wing, these veins bear dense, long silky brownish hairs which, near the margin, are curled and curve upward against the membrane. Palpi and legs yellowish, densely covered with short black hair. Sternum of segment 6 bearing a long conical-shaped process with an acute spine apically; sternum 7 bearing a shorter, slender, conical process, fig. 1B. Genitalia as in fig. 1. Paracercus reaching caudad almost to aedeagus, dorsal margin developed into three large, one short dentate processes (size, shape somewhat variable), apex setiferous. Filacercus long, slender, capitate. Basal segment of clasper large, bulky, apex indented to receive apical segment, mesal margin slightly shelf-